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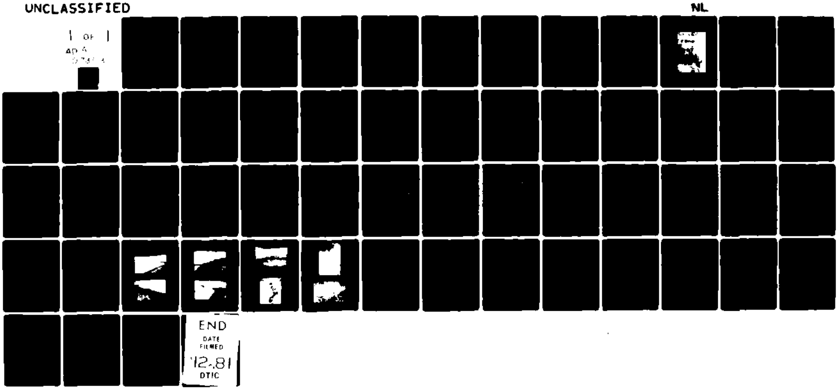

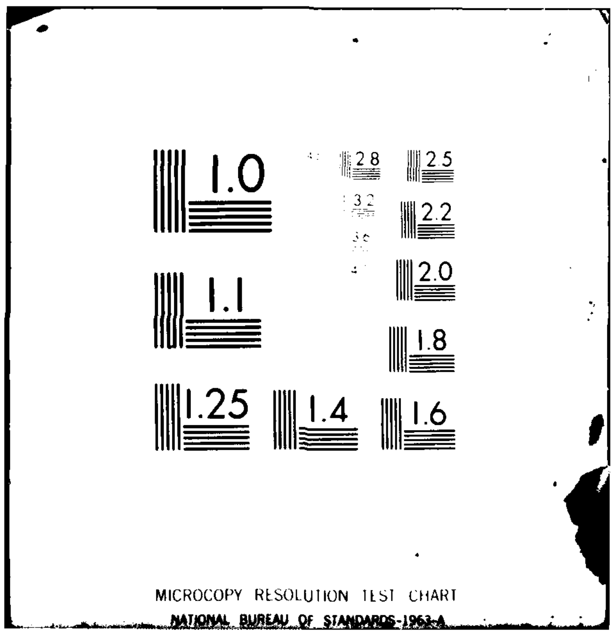
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MISSOURI - KANSAS CITY BASIN

CRANCER LAKE DAM
WARREN COUNTY, MISSOURI
MO 10764

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PHASE 1 INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

**United States Army
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*...Serving the Army
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St. Louis District

PREPARED BY: U.S. ARMY ENGINEER DISTRICT, ST. LOUIS
FOR: STATE OF MISSOURI

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18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Dam Safety, Lake, Dam Inspection, Private Dams

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report was prepared under the National Program of Inspection of Non-Federal Dams. This report assesses the general condition of the dam with respect to safety, based on available data and on visual inspection, to determine if the dam poses hazards to human life or property.

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CRANCER LAKE DAM

WARREN COUNTY, MISSOURI

MO 10764

PHASE 1 INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

United States Army
Corps of Engineers
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St. Louis District

PREPARED BY: U.S. ARMY ENGINEER DISTRICT, ST. LOUIS

FOR: STATE OF MISSOURI

SEPTEMBER 1980

DEPARTMENT OF THE ARMY

ST. LOUIS DISTRICT, CORPS OF ENGINEERS
210 TUCKER BOULEVARD, NORTH
ST. LOUIS, MISSOURI 63101

REPLY TO
ATTENTION OF

LMSED-P

SUBJECT: Crancer Lake Dam, MO 10764

This report presents the results of field inspection and evaluation of the Crancer Lake Dam, MO 10764. It was prepared under the National Program of Inspection of Non-Federal Dams.

SUBMITTED BY: SIGNED — 09 OCT 1980

Chief, Engineering Division — Date

APPROVED BY: SIGNED — 10 OCT 1980

Colonel, CE, District Engineer — Date

CRANCER LAKE DAM

MISSOURI INVENTORY NO. 10764

WARREN COUNTY, MISSOURI

PHASE I INSPECTION REPORT

NATIONAL DAM SAFETY PROGRAM

PREPARED BY:

HORNER & SHIFRIN, INC.
5200 OAKLAND AVENUE
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FOR:

U.S. ARMY ENGINEER DISTRICT, ST. LOUIS

CORPS OF ENGINEERS

SEPTEMBER 1980

HS-8011

PHASE I REPORT

NATIONAL DAM SAFETY PROGRAM

Name of Dam:	Crancer Lake Dam
State Located:	Missouri
County Located:	Warren
Stream:	Tributary of Massie Creek
Date of Inspection:	18 June 1980

Crancer Lake Dam was visually inspected by engineering personnel of Horner & Shifrin, Inc., Consulting Engineers, St. Louis, Missouri. The purpose of this inspection was to assess the general condition of the dam with respect to safety and, based upon this inspection and available data, determine if the dam poses a hazard to human life or property.

The following summarizes the findings of the visual inspection and the results of certain hydrologic/hydraulic investigations performed under the direction of the inspection team. Based on the visual inspection and the results of these hydrologic/hydraulic investigations, the present general condition of the dam is considered to be satisfactory. However, ~~the following~~ deficiencies were noticed during the inspection and are considered to have an adverse effect on the overall safety and future operation of the dam;

1. Seepage, as evidenced by cattails and standing water, was observed at several locations along the junction of the downstream face of the dam and the left abutment, from the upper berm to the toe of the dam. Seepage was also indicated by cattails and standing water at two locations along the original stream channel below the toe of the dam. Uncontrolled seepage could develop into a piping condition (progressive internal erosion) that can lead to failure of the dam.

2. Erosion gullies, apparently due to surface runoff, were observed along the junction of the downstream face of the dam and the right abutment below both the upper and lower berms. Loss of embankment material by erosion can be detrimental to the structural stability of the dam.

3. An erosion gully was also noted at the downstream end of the spillway discharge channel. It appears that the erosion is a result of higher discharge velocities caused by a low berm extending partially across the spillway outlet channel downstream of the concrete weir. While not at present endangering the stability of the dam, the progress of the erosion should be monitored.

4. The dam, according to survey data obtained during the inspection, appears to have settled, perhaps as much as 1.0 foot, in the vicinity of the original stream crossing. The crest of the dam should be uniform throughout without low areas that reduce dam freeboard and penalize spillway capacity.

According to the criteria set forth in the recommended guidelines, the magnitude of the spillway design flood for the Crancer Lake Dam, which is classified as intermediate in size and of high hazard potential, is specified to be the Probable Maximum Flood (PMF). The Probable Maximum Flood (PMF) is the flood that may be expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the region. The PMF is ordinarily accepted as the inflow design flood for dams where failure of the structure would increase the danger to human life.

Results of a hydrologic/hydraulic analysis indicated that the spillway is inadequate to pass lake outflow resulting from a storm of PMF magnitude. The spillway is capable, however, of passing lake outflow resulting from the one percent chance (100-year frequency) flood and the outflow corresponding to about 50 percent of the PMF. According to the St. Louis District, Corps of Engineers, the length of the downstream damage zone, should failure of the dam occur, is estimated to be six miles. Accordingly, within the possible damage zone are five dwellings and several farm buildings.

A review of available data did not disclose that seepage or stability analyses of the dam were performed. This is considered a deficiency and should be rectified.

It is recommended that the Owner take the necessary action in the near future to correct or control the deficiencies and safety defects reported herein.

Harold B. Lockett

Harold B. Lockett
P. E. Missouri E-4189

Albert B. Becker, Jr.

Albert B. Becker, Jr.
P. E. Misouri E-9168

OVERVIEW CRANCER LAKE DAM

PHASE 1 INSPECTION REPORT

NATIONAL DAM SAFETY PROGRAM

CRANCER LAKE DAM - MO 10764

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PHASE I INSPECTION REPORT

NATIONAL DAM SAFETY PROGRAM

CRANCER LAKE DAM - MO 10764

SECTION 1 - PROJECT INFORMATION

1.1 GENERAL

a. Authority. The National Dam Inspection Act, Public Law 92-367, dated 8 August 1972, authorized the Secretary of the Army, through the Corps of Engineers, to initiate a program of safety inspection of dams throughout the United States. Pursuant to the above, the St. Louis District, Corps of Engineers, directed that a safety inspection of the Crancer Lake Dam be made.

b. Purpose of Inspection. The purpose of this visual inspection was to make an assessment of the general condition of the above dam with respect to safety and, based upon available data and this inspection, determine if the dam poses a hazard to human life or property.

c. Evaluation Criteria. This evaluation was performed in accordance with the "Phase I" investigation procedures as prescribed in "Recommended Guidelines for Safety Inspection of Dams," Appendix D to "Report to the Chief of Engineers on the National Program of Inspection of Non-Federal Dams," dated May 1975.

1.2 DESCRIPTION OF PROJECT

a. Description of Dam and Appurtenances. The Crancer Lake Dam is an earthfill type embankment rising approximately 64 feet above the original streambed. The embankment has an upstream slope (above the waterline) of approximately 1v on 2.6h, a crest width of about 19 feet, and a downstream slope varying from 1v on 2.5h to 1v on 3.2h. There are two 25-foot wide berms in the downstream face. The length of the dam is approximately 836 feet. A plan and profile of the dam are shown on Plate 3 and a cross-section of the dam is shown on Plate 4. At normal pool level the reservoir impounded by the

dam occupies approximately 19 acres. The original lake drawdown pipe was filled with concrete and is no longer operative. An overview photo of the Crancer Lake Dam is shown following the preface at the beginning of the report.

The spillway, a concrete weir section 1 foot wide and 50 feet long with low concrete wingwalls at each end, is located at the right or east abutment. The spillway outlet channel downstream of the weir consists of a grass-lined trapezoidal section excavated into the hillside of the right abutment and discharging into a natural draw. A profile of the spillway channel is shown on Plate 4 and a cross-section of the channel is shown on Plate 5. The dam has no emergency spillway.

b. Location. The dam is located on an unnamed tributary of Massie Creek, about six miles southwest of Pendleton, Missouri, just west of State Route B, as shown on the Regional Vicinity Map, Plate 1. The dam is located in the northwest quadrant of Section 6, Township 46 North, Range 3 West, within Warren County.

c. Size Classification. The size classification based on the height of the dam and storage capacity, is categorized as intermediate. (Per Table 1, Recommended Guidelines for Safety Inspection of Dams.)

d. Hazard Classification. Crancer Lake Dam, according to the St. Louis District, Corps of Engineers, has a high hazard potential, meaning that if the dam should fail, there may be loss of life, serious damage to homes, or extensive damage to agricultural, industrial and commercial facilities, important public utilities, main highways, or railroads. The estimated flood damage zone, should failure of the dam occur, as determined by the St. Louis District, extends six miles downstream of the dam. Within the possible damage zone are five dwellings and several farm buildings. Those features lying within the downstream damage zone as reported by the St. Louis District, Corps of Engineers, were verified by the inspection team.

e. Ownership. The lake and dam are owned by Robert E. Crancer. Mr. Crancer's address is: 11 Nolan, Glendale, Missouri 63122.

f. Purpose of Dam. The dam impounds water for recreational use.

g. Design and Construction History. According to the Owner, the dam was constructed in 1965 by Lawrence Handlang, a local grading and excavating contractor. The present status or whereabouts of Mr. Handlang are not known.

h. Normal Operational Procedure. The lake level is unregulated. Lake outflow is governed by the capacity of the concrete weir spillway and its outlet channel.

1.3 PERTINENT DATA

a. Drainage Area. With the exception of some of the land in the vicinity of the lake and dam which is cleared and used for recreation, the drainage area tributary to the lake is for the most part in a native state covered with timber. The watershed above the dam amounts to approximately 104 acres. The watershed area is outlined on Plate 2.

b. Discharge at Damsite.

(1) Estimated known maximum flood at damsite ... 20 cfs* (W.S. Elev. 744.2)
(2) Spillway capacity ... 469 cfs (W.S. Elev. 746.2)

c. Elevation (Ft. above MSL). The following elevations were determined by survey and are based on topographic data shown on the 1973 Jonesburg, Missouri, Quadrangle Map, 7.5 Minute Series.

(1) Observed pool ... 743.5
(2) Normal pool ... 744.0
(3) Spillway crest ... 744.0
(4) Maximum experienced pool ... 744.2*
(5) Top of dam ... 746.2 (min.)
(6) Streambed at centerline of dam ... 682$\pm$(est.)
(7) Maximum tailwater ... Unknown
(8) Observed tailwater ... None

*Based on an estimate of depth of flow at spillway as observed by the Owner.

d. Reservoir.

(1) Length at normal pool (Elev. 744.0) ... 1,050 ft.

(2) Length at maximum pool (Elev. 746.2) ... 1,100 ft.

e. Storage.

(1) Normal pool ... 347 ac. ft.

(2) Top of dam (incremental) ... 45 ac. ft.

f. Reservoir Surface.

(1) Normal pool ... 19 acres

(2) Top of dam (incremental) ... 2 acres

g. Dam. The height of the dam is defined to be the overall vertical distance from the lowest point of foundation surface at the downstream toe of the barrier to the top of the dam.

(1) Type ... Earthfill, clay core*

(2) Length ... 836 ft.

(3) Height ... 64 ft.

(4) Top width ... 19 ft.

(5) Side slopes

a. Upstream ... 1v on 2.6h (above waterline)

b. Downstream ... variable, 1v on 2.5h to 1v on 3.2h (with 2-25 ft. wide berms on downstream face)

(6) Cutoff ... Clay core*

(7) Slope protection

a. Upstream ... Quarry-run limestone riprap and grass

b. Downstream ... Grass

*Per Owner

h. Principal Spillway.

(1) Type ... Uncontrolled, 1 foot wide by 50 feet long concrete weir

(2) Location ... Right abutment

(3) Crest ... Elevation 744.0

(4) Approach channel ... Lake

(5) Exit channel ... Earth, trapezoidal section

i. Emergency Spillway. ... None

j. Lake Drawdown Facility. According to the Owner, a 6-inch diameter steel pipe with anti-seepage collars and a valve was provided to dewater the lake. The Owner reports that the pipe outlet is covered with fill, and the valve and pipe are plugged with concrete.

SECTION 2 - ENGINEERING DATA

2.1 DESIGN

According to the Owner, engineering data relating to the design of the dam do not exist.

2.2 CONSTRUCTION

No formal records were maintained during construction of the dam. However, as previously stated, the dam was constructed in 1965 by Lawrence Handlang, a local grading and excavating contractor. According to the Owner, a core trench was excavated to rock, and backfilled with clay from the adjacent hillsides; and the material in the embankment was compacted with a sheepsfoot roller. The Owner reported that the dam crest settled about 6 inches during the first 5 years after construction, and was later rebuilt to the original grade.

2.3 OPERATION

The lake level is uncontrolled and governed by the crest elevation of the concrete weir located at the right abutment of the dam. The Owner reported that the dam has never been overtopped and that the maximum flood experienced by the dam occurred when a storm produced a depth of flow at the weir estimated to be about 2 inches. No indication that the dam had been overtopped was noticed during the inspection.

2.4 EVALUATION

a. Availability. Engineering data for assessing the design of the dam and spillway were unavailable.

b. Adequacy. No data available. Seepage and stability analyses comparable to the requirements of the "Recommended Guidelines for Safety

Inspection of Dams" were not available, which is considered a deficiency. These seepage and stability analyses should be performed for appropriate loading conditions (including earthquake loads) and made a matter of record.

SECTION 3 - VISUAL INSPECTION

3.1 FINDINGS

a. General. A visual inspection of the Crancer Lake Dam was made by Horner & Shifrin engineering personnel, T. K. Deddens, Geological Engineer, and H. B. Lockett, Civil Engineer and Hydrologist, on 18 June 1980. An examination of the dam area was also made by an engineering geologist, Jerry D. Higgins, Ph.D., a consultant retained by Horner & Shifrin for the purpose of assessing the site geology. Also examined at the time of the inspection were the areas and features below the dam within the potential flood damage zone. Photographs of the dam taken at the time of the inspection are included on pages A-1 through A-4 of Appendix A. The locations of the photographs taken during the inspection are indicated on Plate 3.

b. Site Geology. The Crancer Lake Dam is located near the northern edge of the Ozark Plateaus Physiographic Province, close to the border with the Dissected Till Plains Section of the Central Lowlands Physiographic Province. The topography is moderately rolling at the reservoir site, becoming steeper immediately downstream. Relief between the lake site and the surrounding drainage divides ranges up to approximately 95 feet. The bedrock consists of gently northward-dipping Mississippian-age sedimentary strata. Bedrock exposures immediately downstream from the dam embankment indicate the dam is underlain by the undifferentiated Chouteau group. The bedrock is dipping slightly to the north, and no faults were observed or are reported to be present in this area.

The undifferentiated Chouteau consists primarily of finely crystalline, thinly- to thickly-bedded limestones. Chert is locally present. These limestones are susceptible to solution weathering as illustrated by the pinnacled bedrock exposures downstream from the embankment. Solution-enlarged joints and bedding planes are common in this type of bedrock and may cause reservoir leakage.

The unconsolidated surficial materials in the vicinity of the reservoir are composed principally of soils derived from loess and glacial till, as well as from bedrock residuum. The dam site and reservoir are underlain by soils of the Goss and Lindley series. The Goss soils, which cover the valley floor, consist of deep, well-drained soils formed in material weathered from cherty limestone. The soil typically ranges from a dark grayish-brown to brown, very cherty, silty clay at the surface to a yellowish-brown, firm, very cherty clay at depth. According to the Unified Soil Classification System the soil ranges from a GM to GC material, is moderately permeable, and compressible. Reportedly, seepage from water impoundments is common in these soils. The side slopes are covered with soils of the Lindley series. These are deep, well-drained soils formed on glacial till. The soil is typically a silty clay at the surface, becoming more clayey with depth. Chert fragments are common, especially in the surface layer. The soils are classified as CL-ML to CL materials, exhibit moderately low permeability, and are generally considered favorable for impoundments and embankments. The surrounding uplands are covered with soils of the Hatton series. These are moderately well-drained clays and silty clays formed from loess and the underlying glacial sediment. These soils are only present well above the reservoir and dam site.

It appears the most significant geologic conditions at the dam site are the solution-weathered bedrock overlain by the permeable cherty clay residuum.

c. Dam. The visible portions of the upstream and downstream faces of the dam as well as the dam crest (see Photos 1 through 3) were inspected and appeared to be structurally sound. However, erosion gullies, apparently due to surface runoff, were observed along the junction of the downstream face of the dam and the right abutment below both the upper and lower berms. The dam was well covered with a good stand of grass, and no trees or brush were noted on the dam proper.

The upstream face of the dam was protected against erosion by 4-inch minus quarry-run crushed limestone extending about 3 feet above the normal water surface. Minor surface cracks (due to shrinkage of the soil because of dry weather) were noted at several locations along the dam crest. No misalignment of the dam crest or sloughing of the dam slopes was noticed. An examination

of the surficial material near the crest of the dam indicated the soil to be a silty lean clay (CL) of low-to-medium plasticity.

According to survey data obtained at the time of the inspection, the lowest part of the dam crest was found to be between station 6+50 and 6+90, about the location of the original stream on which the dam was constructed. The top of dam at this location was found to be approximately 1.0 foot lower than the top of dam at locations 100 feet, or so, either side of this location. It would appear, based on these elevations, that the dam has settled at the location of the original stream crossing.

Underseepage, as evidenced by cattails and standing water (see Photos 7 and 8) was observed at the junction of the downstream face of the dam and the left abutment at several locations from the upper berm to the toe of the dam. Seepage, as indicated by cattails and standing water, was also noticed at two locations along the original stream course below the toe of the dam. Since flow was not apparent, an estimate of the amount of seepage occurring at these locations could not be made.

The concrete weir (see Photo 4) at the spillway outlet channel was found to be in good condition without evidence of cracking or spalling of the surface. The outlet channel below the weir (see Photo 5) was generally in good condition, with a substantial turf cover. However, at the downstream end of the outlet channel, an erosion gully (see Photo 6) was noted. A low berm, extending partially across the spillway outlet channel downstream of the weir, was also noted. The berm appeared to concentrate flow in the channel toward the left bank, resulting in erosion of the channel invert.

d. Downstream Channel. The unimproved channel downstream of the dam extends for approximately 1.2 miles before joining Massie Creek. Massie Creek is unimproved.

e. Reservoir. The area adjacent to the lake is in a well maintained natural state and wooded. The amount of sediment in the lake at the time of inspection could not be determined; however, due to the vegetation covering the surrounding area, it is believed to be insignificant.

3.2 EVALUATION

The deficiencies observed during the inspection and noted herein, are not considered of significant importance to warrant immediate remedial action. The stone riprap slope protection on the upstream face of the dam is considered adequate to prevent erosion of the embankment by wave action or by fluctuations of the lake level.

SECTION 4 - OPERATIONAL PROCEDURES

4.1 PROCEDURES

The spillway is uncontrolled. The water surface level is governed by precipitation runoff, evaporation, seepage, and the capacity of the uncontrolled spillway.

4.2 MAINTENANCE OF DAM

With the exception of the seepage at the left abutment and the erosion gullies at the right abutment and at the downstream end of the spillway discharge channel, the dam is well maintained, with no brush or tree growth on the dam faces. According to Mr. Shorty Slatten, Caretaker, the grass on the dam is cut periodically during the growing season. Mr. Slatten also reported that the berm within the spillway outlet channel just downstream of the concrete weir is to be removed sometime in the near future.

4.3 MAINTENANCE OF OPERATING FACILITIES

No outlet facilities requiring operation exist at this dam.

4.4 DESCRIPTION OF ANY WARNING SYSTEM IN EFFECT

The inspection did not reveal the existence of a dam failure warning system.

4.5 EVALUATION

It is recommended that records be kept of all major items of maintenance work performed. It is also recommended that a detailed inspection of the dam be instituted on a regular basis by an engineer experienced in the design and construction of dams and that records be kept of all inspections made and remedial measures taken.

SECTION 5 - HYDRAULIC/HYDROLOGIC

5.1 EVALUATION OF FEATURES

a. Design Data. Design data were not available.

b. Experience Data. The drainage area and lake surface area were developed from the 1973 USGS Jonesburg, Missouri, Quadrangle Map. The proportions and dimensions of the spillway and dam were developed from surveys made during the inspection. Records of rainfall, streamflow, or flood data for the watershed are not available.

Due to the fact that the watershed for this reservoir is small, the lake level was assumed to be at normal pool as a result of antecedent storms prior to occurrence of the PMF and the probabilistic storm.

According to the St. Louis District, Corps of Engineers, the estimated flood damage zone, should failure of the dam occur, extends six miles downstream of the dam.

c. Visual Observations.

(1) The principal spillway crest section consists of a concrete weir (wall) 50 feet long and 12 inches wide, and is located at the right abutment of the dam. The pipe posts embedded in the concrete wall were considered to be hydraulically unimportant.

(2) The spillway outlet channel, a trapezoidal shaped grass-lined section, directs flow into a natural watercourse removed from the downstream face of the dam.

(3) The Owner reported that a 6-inch steel pipe and valve (blocked with concrete and covered with fill) was originally provided to dewater the lake.

d. Overtopping Potential. The spillway is inadequate to pass the probable maximum flood without overtopping the dam. The spillway is adequate, however, to pass 1/2 the probable maximum flood without overtopping the dam. The results of the dam overtopping analyses are as follows:

(Note: The data appearing in the following table has been extracted from the computer output data appearing in Appendix B. Decimal values have been rounded to the nearest one-tenth in order to prevent assumption of unwarranted accuracy.)

Ratio of PMF	Q-Peak Outflow (cfs)	Max Lake W.S. Elev.	Max. Depth (Ft.) of Flow over Dam (Elev. 746.2)	Duration of Overtopping of Dam (Hours)
0.50	435	746.1	0	0
1.00	1483	747.2	1.0	1.3

Elevation 746.2 was found to be the lowest point in the dam crest. The flow safely passing the spillway just prior to overtopping amounts to approximately 469 cfs, which is the routed outflow corresponding to about 50 percent of the probable maximum flood inflow. During peak flow of the probable maximum flood, the greatest depth of flow over the dam is projected to be 1.0 feet and overtopping will extend across about 415 feet of the dam.

e. Evaluation. Examination of the surficial material on the dam indicated it to be a silty lean clay of low-to-medium plasticity. Experience indicates that this type of material under certain conditions such as high velocity flow, can be quite erodible. Such a condition exists during the PMF when large lake outflow, accompanied by high flow velocities, occurs. For the PMF condition a certain amount of damage by erosion to the crest and downstream face of the dam is expected. However, since the depth of flow over the dam crest, a maximum of 1.0 feet, and the duration of flow over the dam, 1.3 hours, are considered to be relatively minor, and since the downstream face and the dam crest are protected by a substantial cover of grass, failure of the dam by erosion during overtopping by the PMF is not expected.

f. Reference. Procedures and data for determining the probable maximum flood, the 100-year frequency flood, and the discharge rating curve for flow passing the spillway and dam crest are presented on pages B-1 and B-2 of the Appendix. Listings of the HEC-1 (Dam Safety Version) input data for both the probable maximum flood and the 100-year frequency flood are shown on pages B-3 through B-5. Computer output data, including unit hydrograph ordinates, tabulation of PMF rainfall, loss and inflow data are shown on pages B-6 through B-9; tabulation of lake surface area, elevation and storage volume is shown on page B-10; and tabulations titled "Summary of Dam Safety Analysis" for the PMF and 1 percent chance (100-year frequency) flood are also shown on page B-10.

SECTION 6 - STRUCTURAL STABILITY

6.1 EVALUATION OF STRUCTURAL STABILITY

a. Visual Observations. Visual observations of conditions which adversely affect the structural stability of the dam are discussed in Section 3, paragraph 3.1c.

b. Design and Construction Data. No design or construction data relating to the structural stability of the dam are known to exist. Seepage and stability analyses comparable to the requirements of the "Recommended Guidelines for Safety Inspection of Dams" were not available, which is considered a deficiency. These seepage and stability analyses should be performed for appropriate loading conditions (including earthquake loads) and made a matter of record.

c. Operating Records. No appurtenant structures or facilities requiring operation exist at this dam. According to the Owner, no records are kept of the lake level, spillway discharge, dam settlement, or seepage.

d. Post Construction Changes. With the exception of rebuilding the dam to the original height after settlement of 6 inches during a 5 year period following construction and plugging the drainpipe and valve with concrete, the Owner reported that no post construction changes have been made or have occurred which would affect the structural stability of the dam.

e. Seismic Stability. The dam is located in an area close to the boundary separating the Zone I and Zone II seismic probability areas. An earthquake of the magnitude that might occur in this area would not be expected to cause structural damage to a well constructed earth dam of this size provided that static stability conditions are satisfactory and conventional safety margins exist. However, it is recommended that the prescribed seismic loading be applied in any stability analyses performed for this dam.

SECTION 7 - ASSESSMENT/REMEDIAL MEASURES

7.1 DAM ASSESSMENT

a. Safety. A hydraulic analysis indicated that the spillway is capable of passing lake outflow of about 469 cfs without the level of the lake exceeding the low point in the top of the dam. A hydrologic analysis of the lake watershed area, as discussed in Section 5, paragraph 5.1d, indicated that for storm runoff of probable maximum flood magnitude, the recommended spillway design flood, the lake outflow would be on the order of 1,483 cfs, and that for the 1 percent chance (100-year frequency) flood, the lake outflow would be about 126 cfs.

Several items were noticed during the inspection that could adversely affect the safety of the dam. These items include seepage, the areas of significant erosion of the downstream face of the dam and the spillway discharge channel, and the presence of a low berm across the outlet channel that could impede spillway discharges.

Seepage and stability analyses of the dam were not available for review, and therefore, no judgment could be made with respect to the structural stability of the dam.

b. Adequacy of Information. Due to lack of design and construction data, the assessments reported herein were based on external conditions as determined during the visual inspection. The assessment of the hydrology of the watershed and capacity of the spillways were based on a hydrologic/hydraulic study as indicated in Section 5. Seepage and stability analyses comparable to the requirements of the "Recommended Guidelines for Safety Inspection of Dams" were not available, which is considered a deficiency.

c. Urgency. The remedial measures recommended in paragraph 7.2 for the items concerning the safety of the dam noted in paragraph 7.1a should be accomplished within a reasonable time.

d. Necessity for Phase II. Based on the results of the Phase I inspection, a Phase II investigation is not recommended.

e. Seismic Stability. The dam is located in an area close to the boundary separating the Zone I and Zone II seismic probability areas. An earthquake of the magnitude that might occur in this area would not be expected to cause structural damage to a well constructed earth dam of this size provided that static stability conditions are satisfactory and conventional safety margins exist. However, it is recommended that the prescribed seismic loading be applied in any stability analyses performed for this dam.

7.2 REMEDIAL MEASURES

a. Recommendations. The following actions are recommended:

(1) Based upon criteria set forth in the recommended guidelines, spillway size and/or height of dam should be increased in order to pass lake outflow resulting from a storm of probable maximum flood magnitude, which is the recommended spillway design flood for this dam. In either case, the spillway should be protected to prevent erosion.

(2) Obtain the necessary soil data and perform dam seepage and stability analyses in order to determine the structural stability of the dam for all operational conditions. Seepage and stability analyses should be performed by a qualified professional engineer experienced in the design and construction of earthen dams.

(3) Restore the dam crest to a uniform elevation and monitor the top of the dam through the area of suspected settlement in order to determine the extent of possible future settlement and the remedial work required to compensate for such settlement. In any event, the crest of the dam should be uniform throughout without low areas that reduce dam freeboard and penalize spillway capacity.

b. <u>Operations and Maintenance (O & M) Procedures</u>. The following O & M Procedures are recommended:

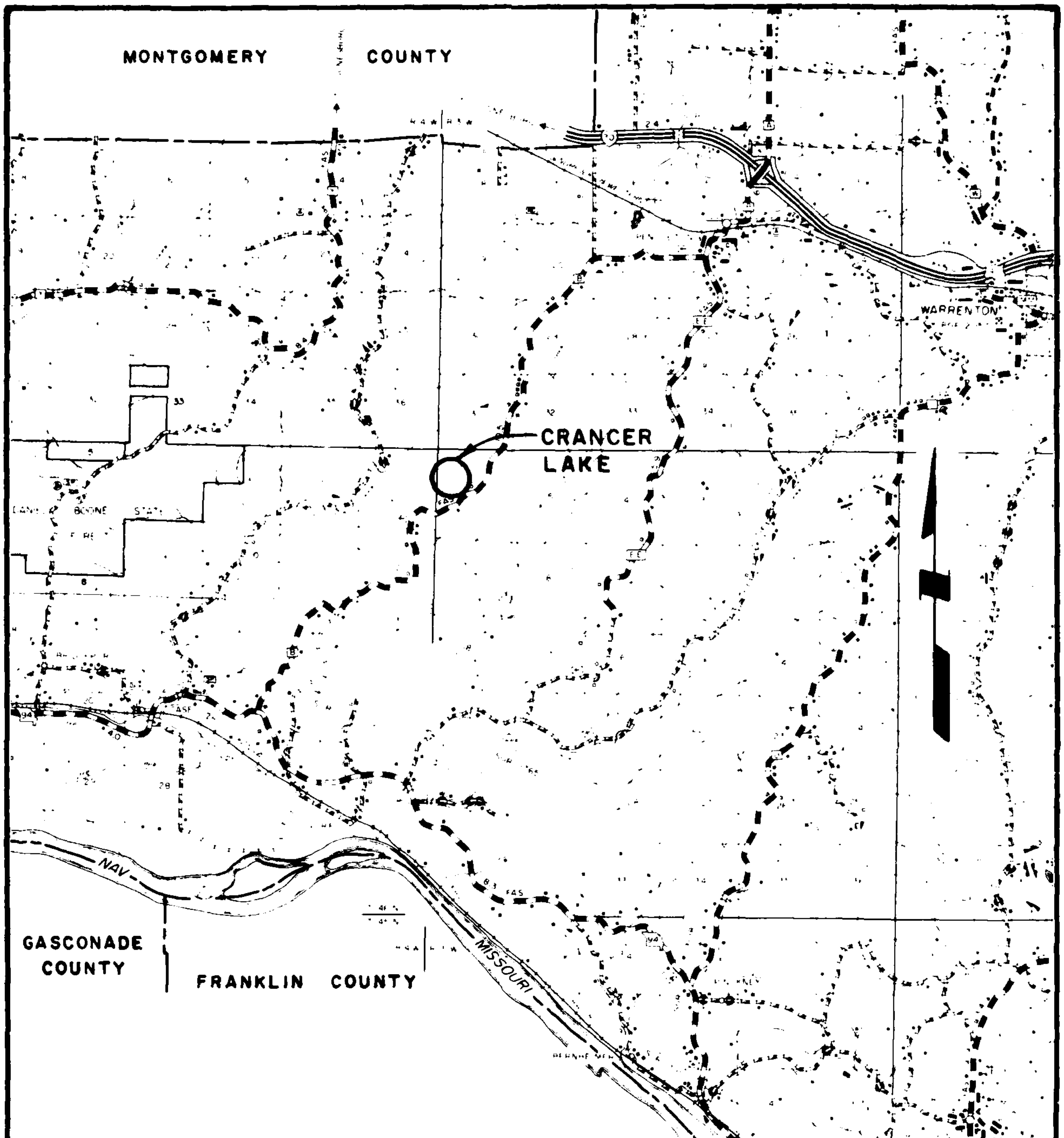
(1) Provide some means of controlling seepage evident in the area adjacent to the downstream face at the left abutment of the dam and in the original creek channel below the dam. Uncontrolled seepage can lead to a piping condition (progressive internal erosion) which could result in failure of the dam.

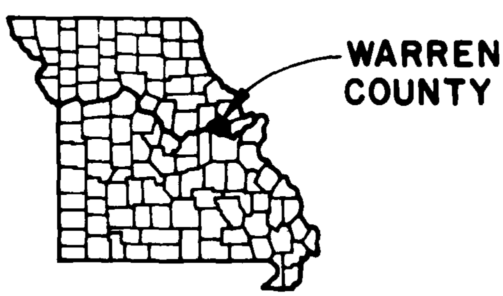
(2) Restore the eroded areas of the dam and provide some means of preventing future erosion. Loss of material due to erosion can impair the structural stability of the dam.

(3) Remove the low berm partially across the spillway outlet channel below the concrete weir in order to permit unobstructed flow in the channel.

(4) Monitor progress of erosion of the lower end of the spillway outlet channel invert. Should erosion of the channel progress toward the spillway weir to a point where the stability of the weir is endangered, then appropriate measures should be taken to check the erosion.

(5) A detailed inspection of the dam should be instituted on a regular basis by an engineer experienced in the design and construction of dams. It is also recommended, for future reference, that records be kept of all inspections made and remedial measures taken.



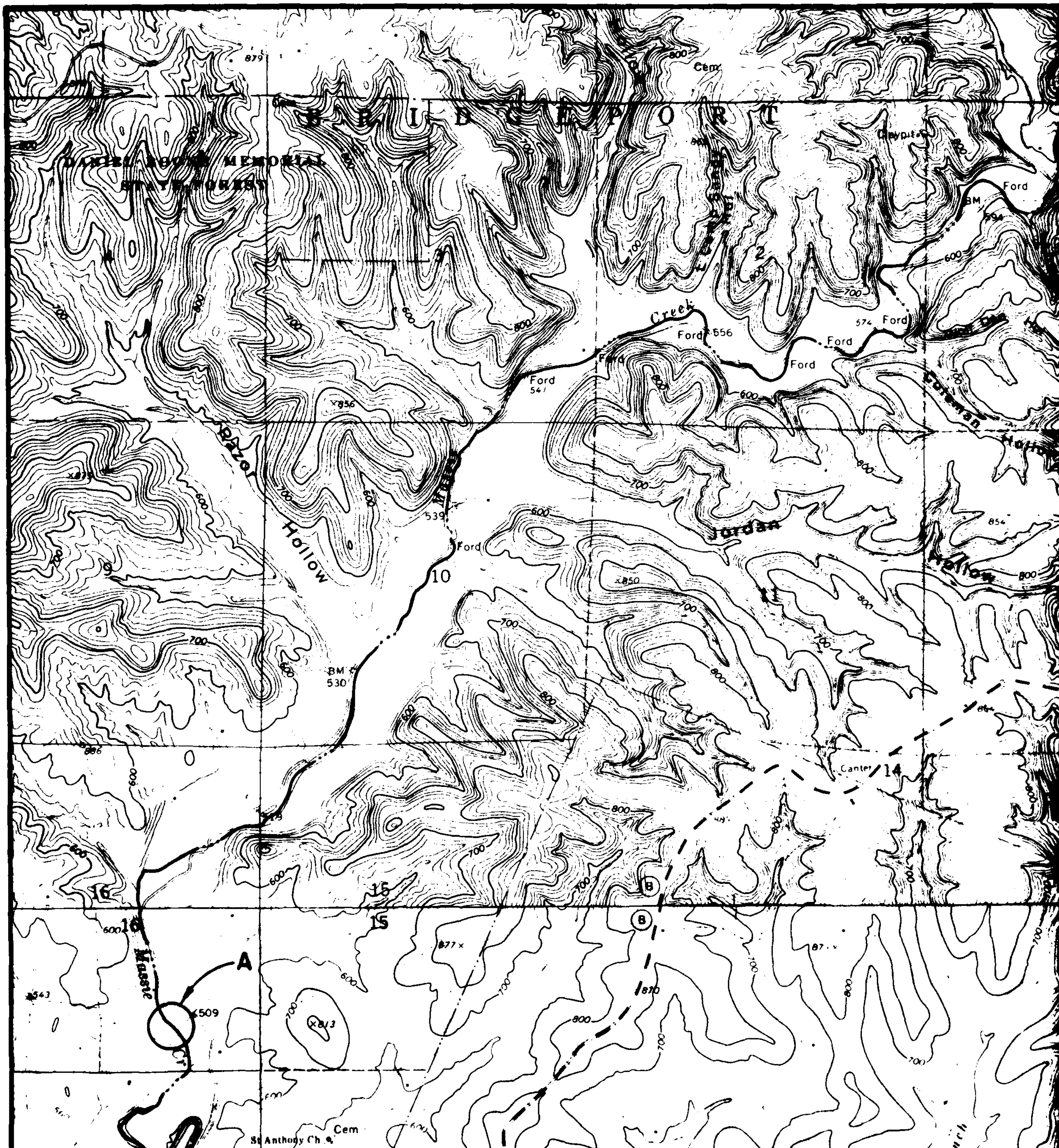


LOCATION MAP

CRANCER LAKE

REGIONAL VICINITY MAP

PLATE I



B R I D G E P O R T
DANIEL BOONE MEMORIAL STATE FOREST
Cem
Ford
Creek
Ford 556
Ford 541
Razor Hollow
Jordan
Hollow
Coleman Hollow
Canter
Massie Cr
A
x509
St Anthony Ch
Cem
Branch
Grave
A=APPROXIMATE EXTENT OF DOWNSTREAM DAMAGE

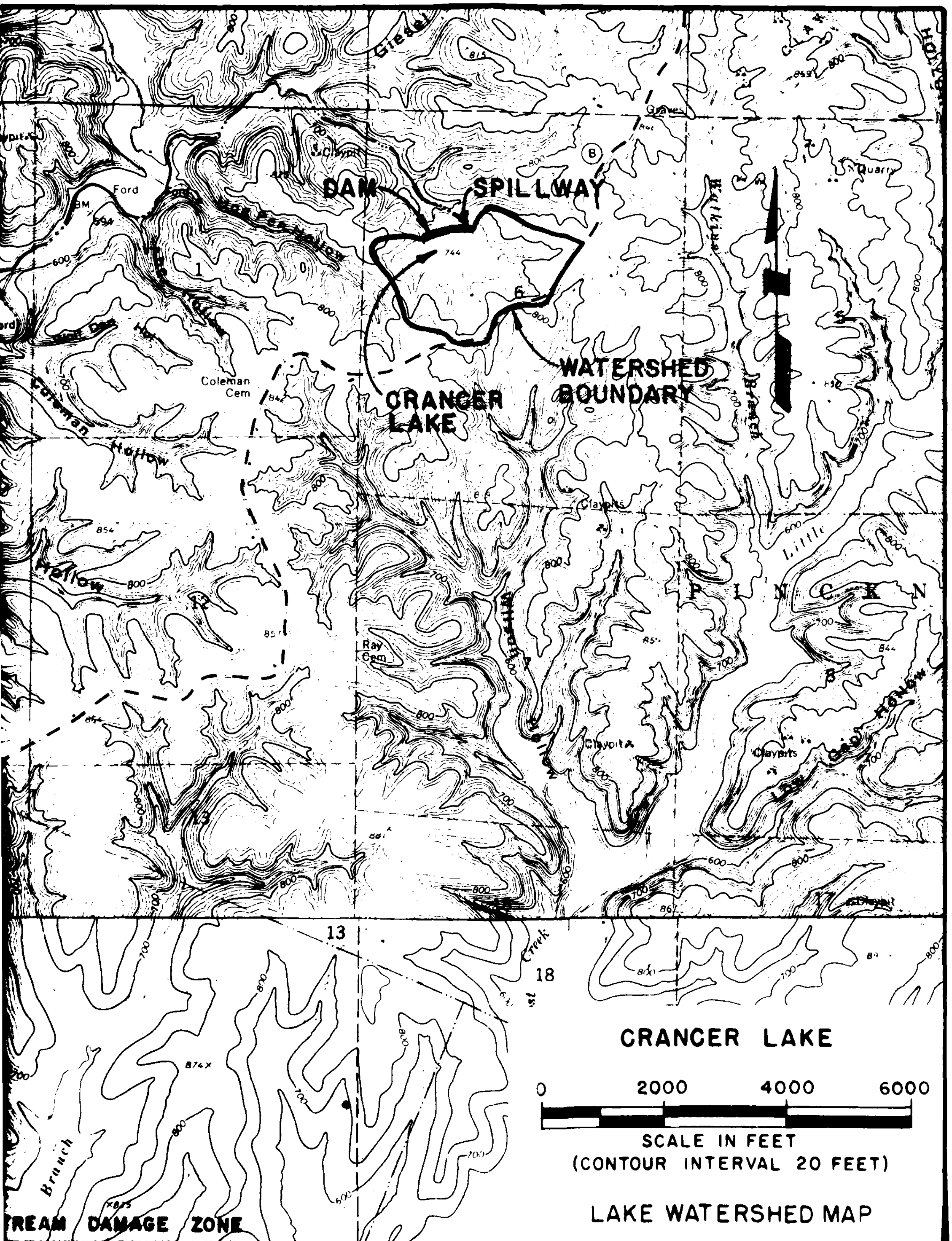
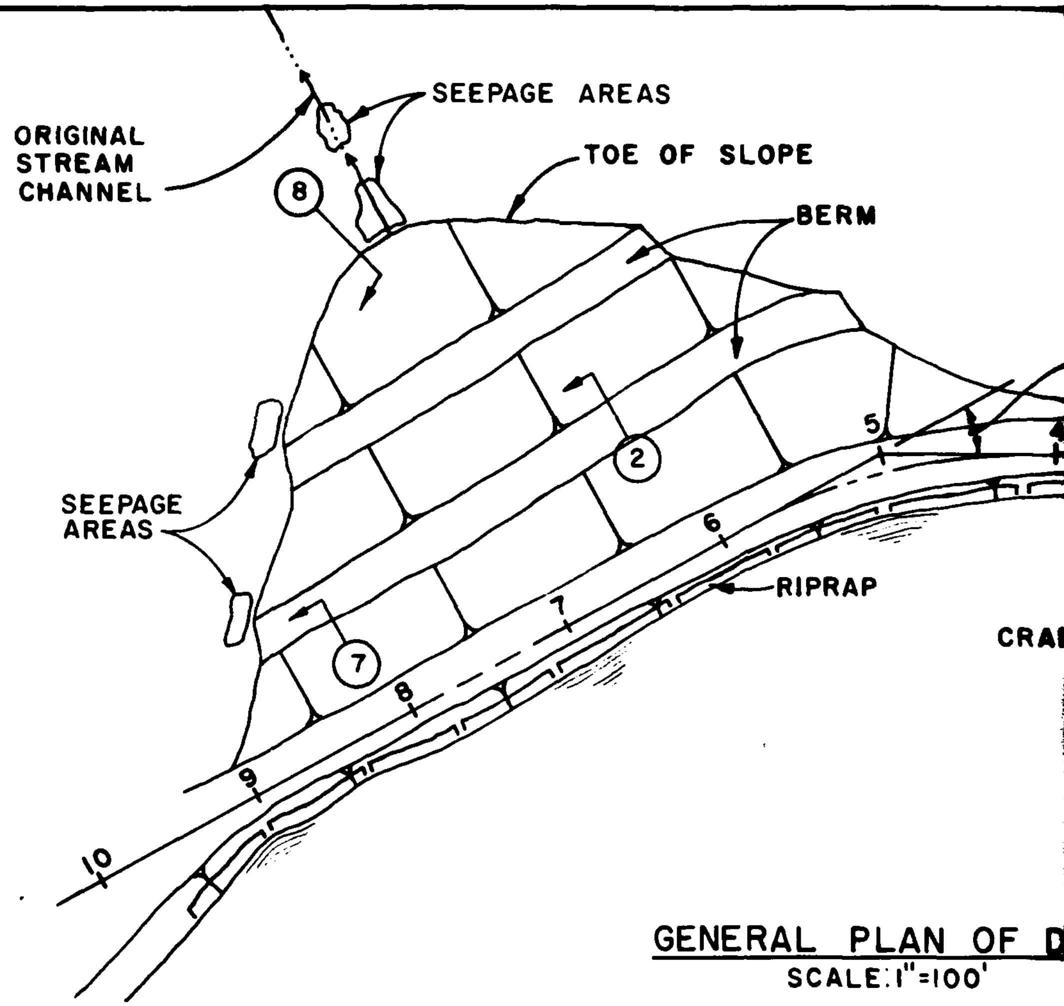

DAM
SPILLWAY
WATERSHED BOUNDARY
CRANGER LAKE
Coleman Cem
Ray Cem
Claypits
Quarry
Ford
Giedel
P I N C K N
STREAM DAMAGE ZONE
CRANGER LAKE
0 2000 4000 6000
SCALE IN FEET
(CONTOUR INTERVAL 20 FEET)
LAKE WATERSHED MAP

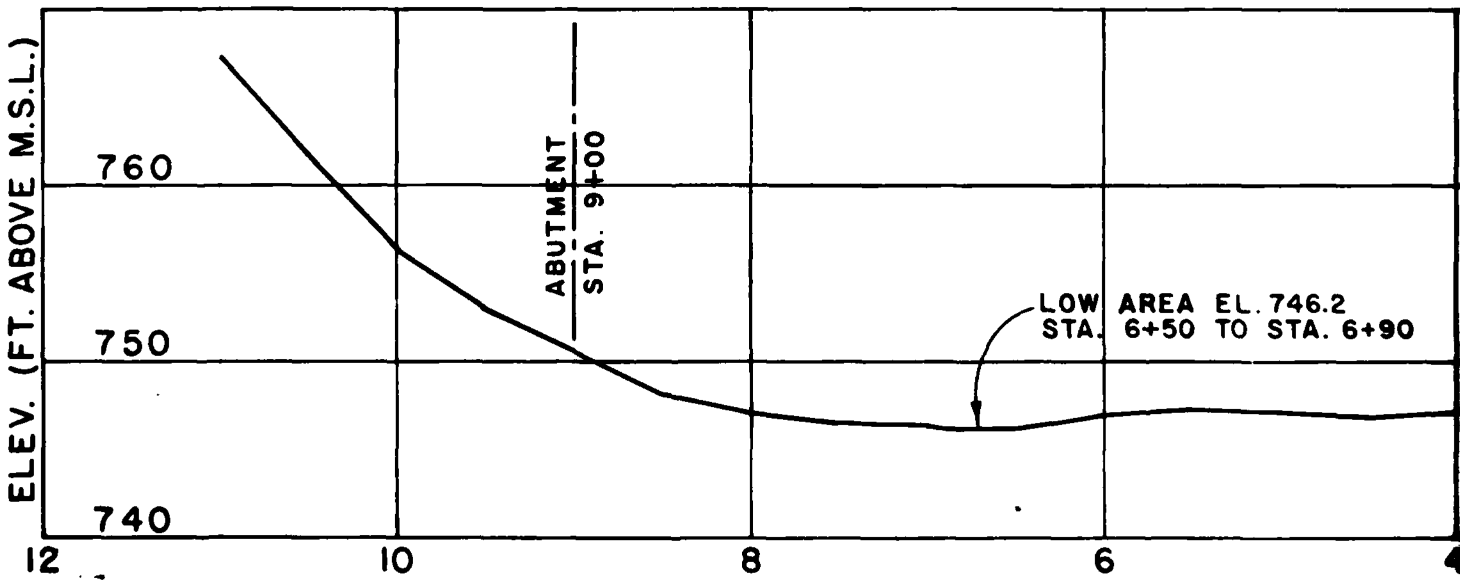
PLATE 2

1 12



GENERAL PLAN OF D

SCALE: 1"=100'

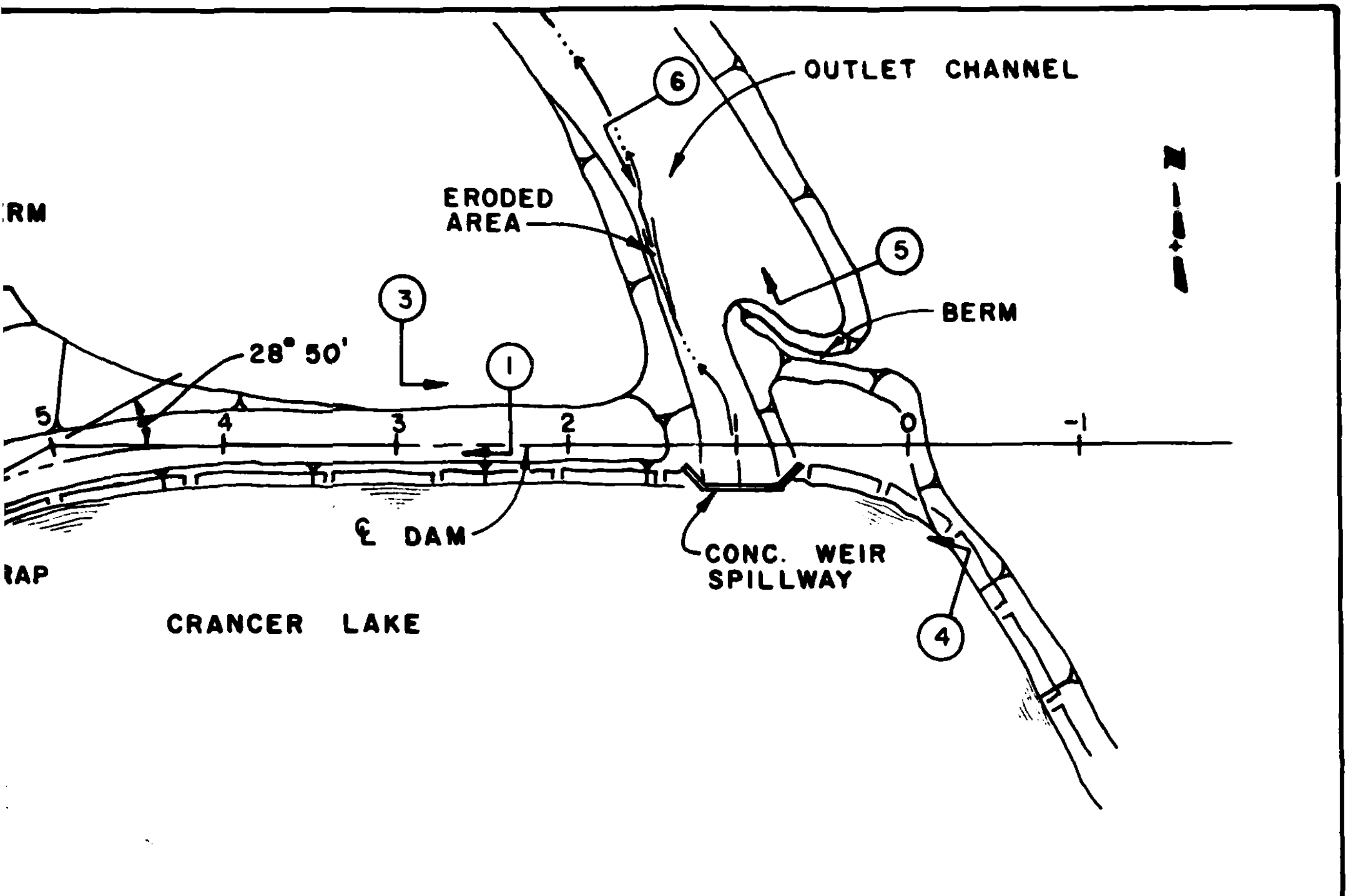


6

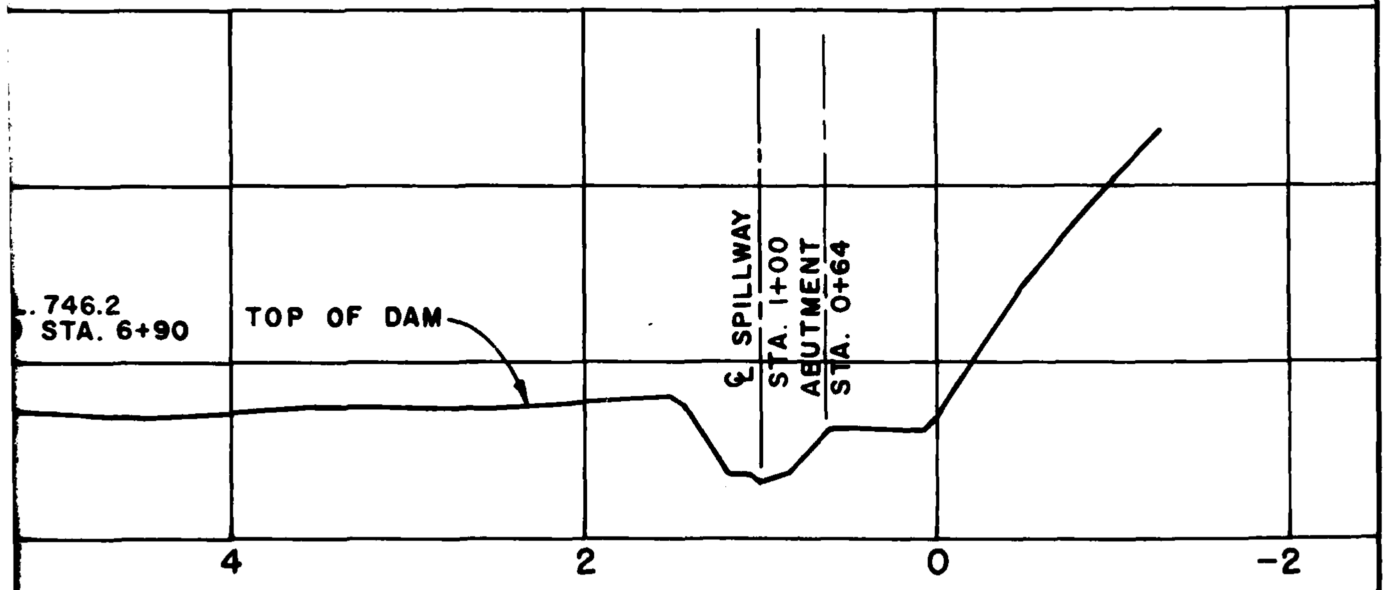
PHOTO LOCATION & KEY
(SEE APPENDIX A)

PROFILE DAM CRES

SCALES: 1"=10'V., 1"=100'H



PLAN OF DAM
LE: 1"=100'

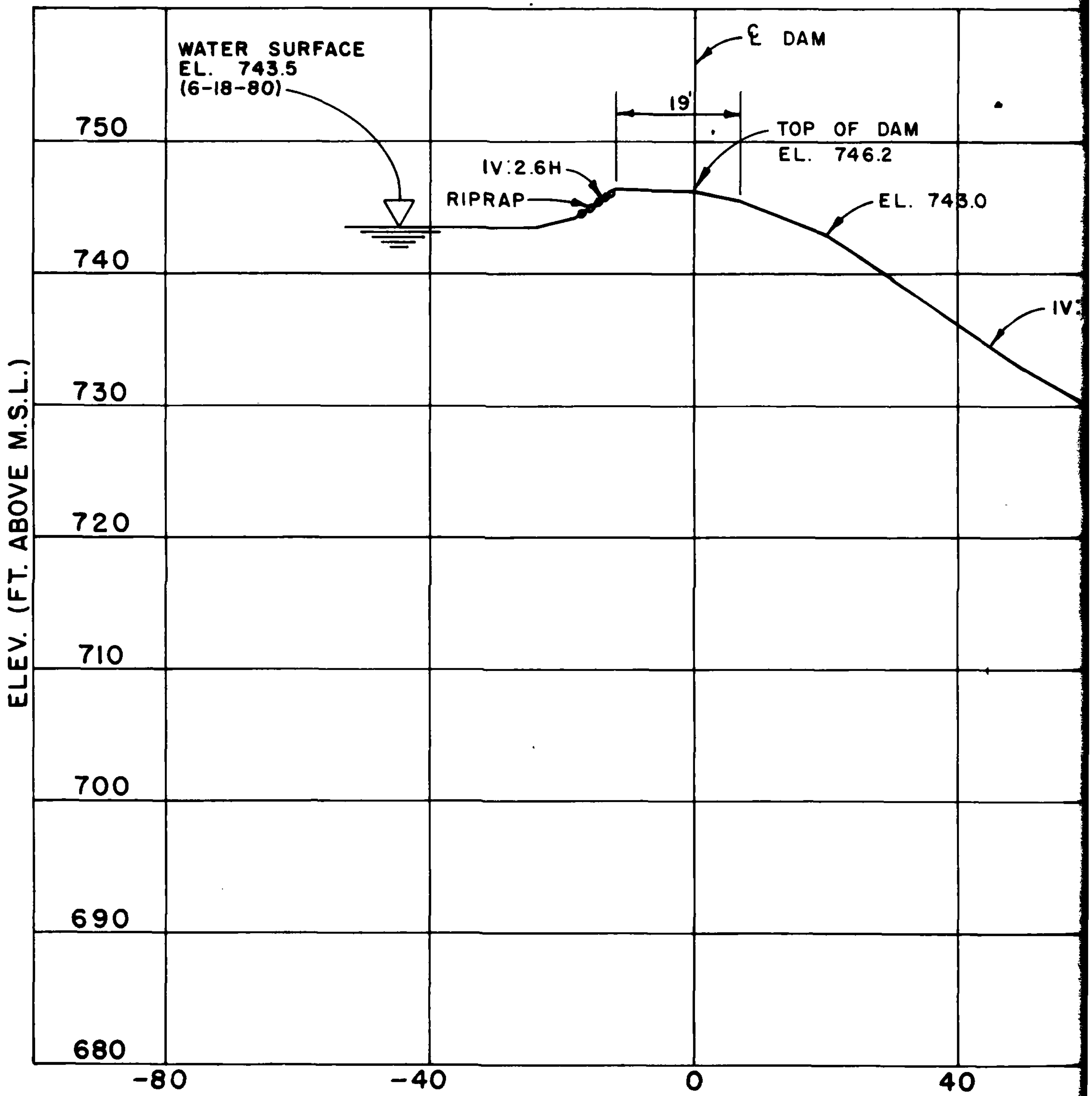


DAM CREST
"=10'V., 1"=100'H.

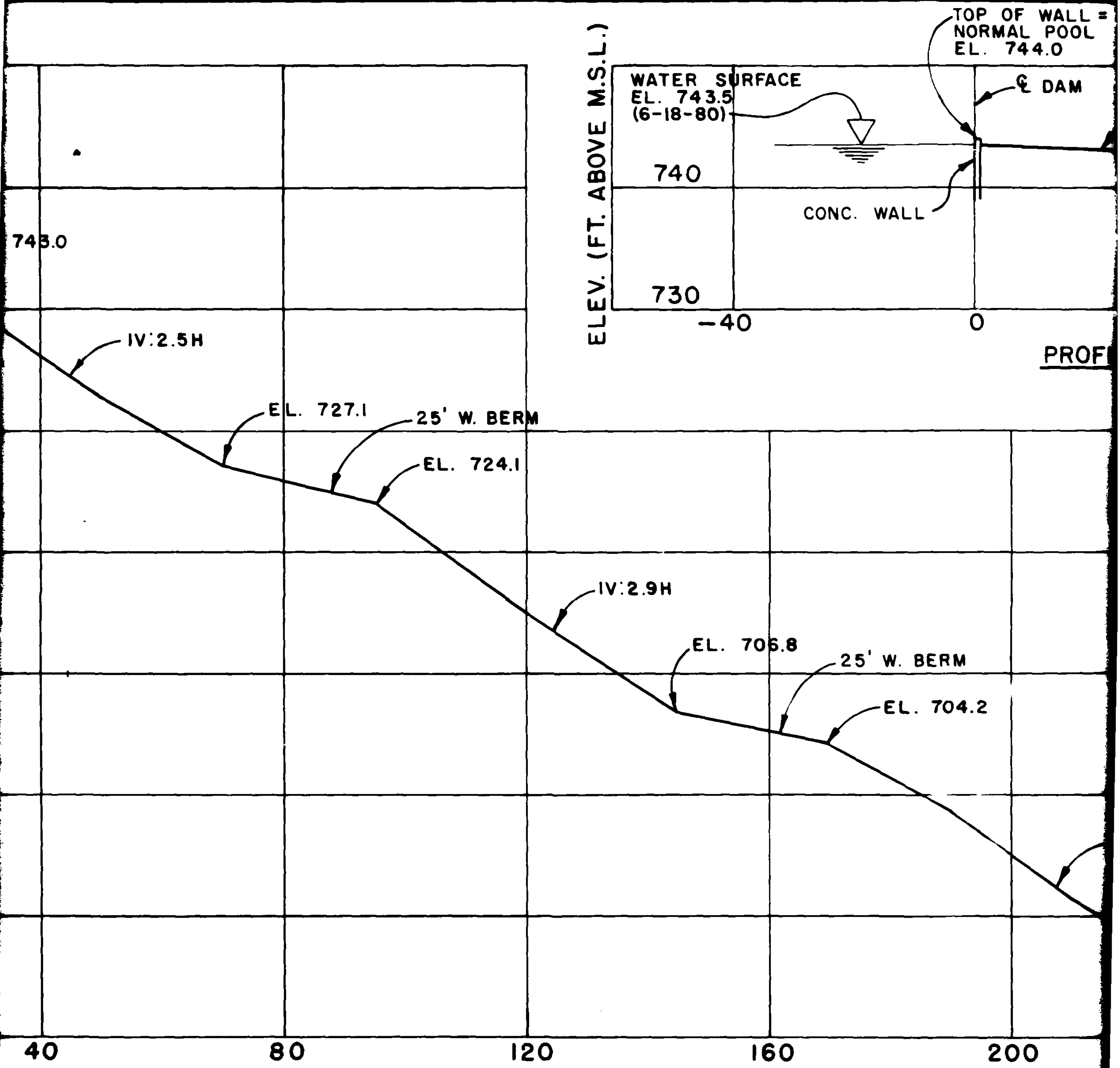
CRANCER LAKE
DAM PLAN & PROFILE

Horner & Shifrin, Inc. July 1980

PLATE 3

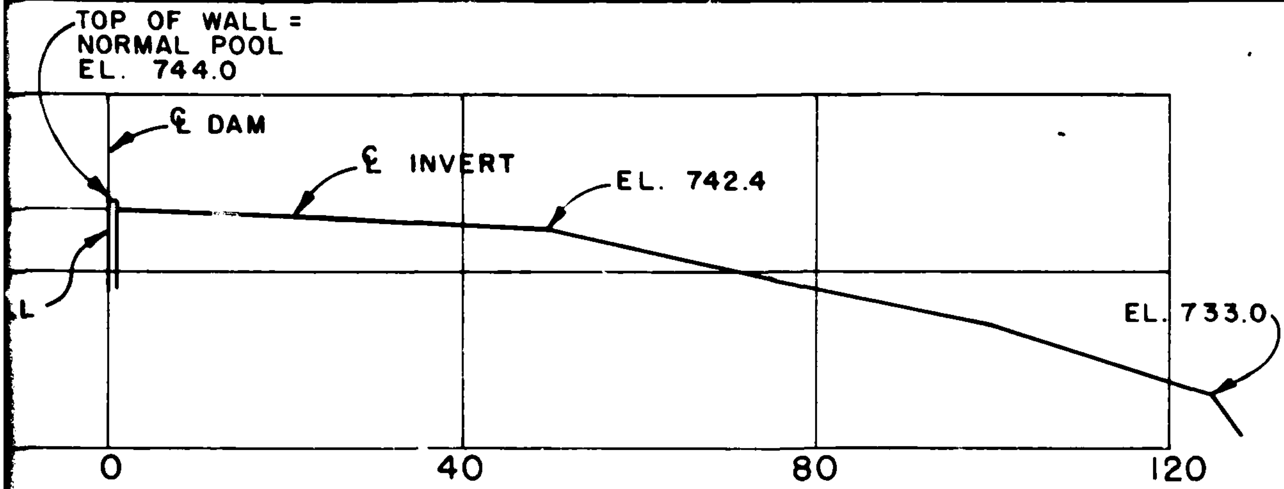


WATER SURFACE
EL. 743.5
(6-18-80)
℄ DAM
19'
TOP OF DAM
EL. 746.2
1V:2.6H
RIPRAP
EL. 743.0
1V:
750
740
730
720
710
700
690
680
ELEV. (FT. ABOVE M.S.L.)
-80
-40
0
40



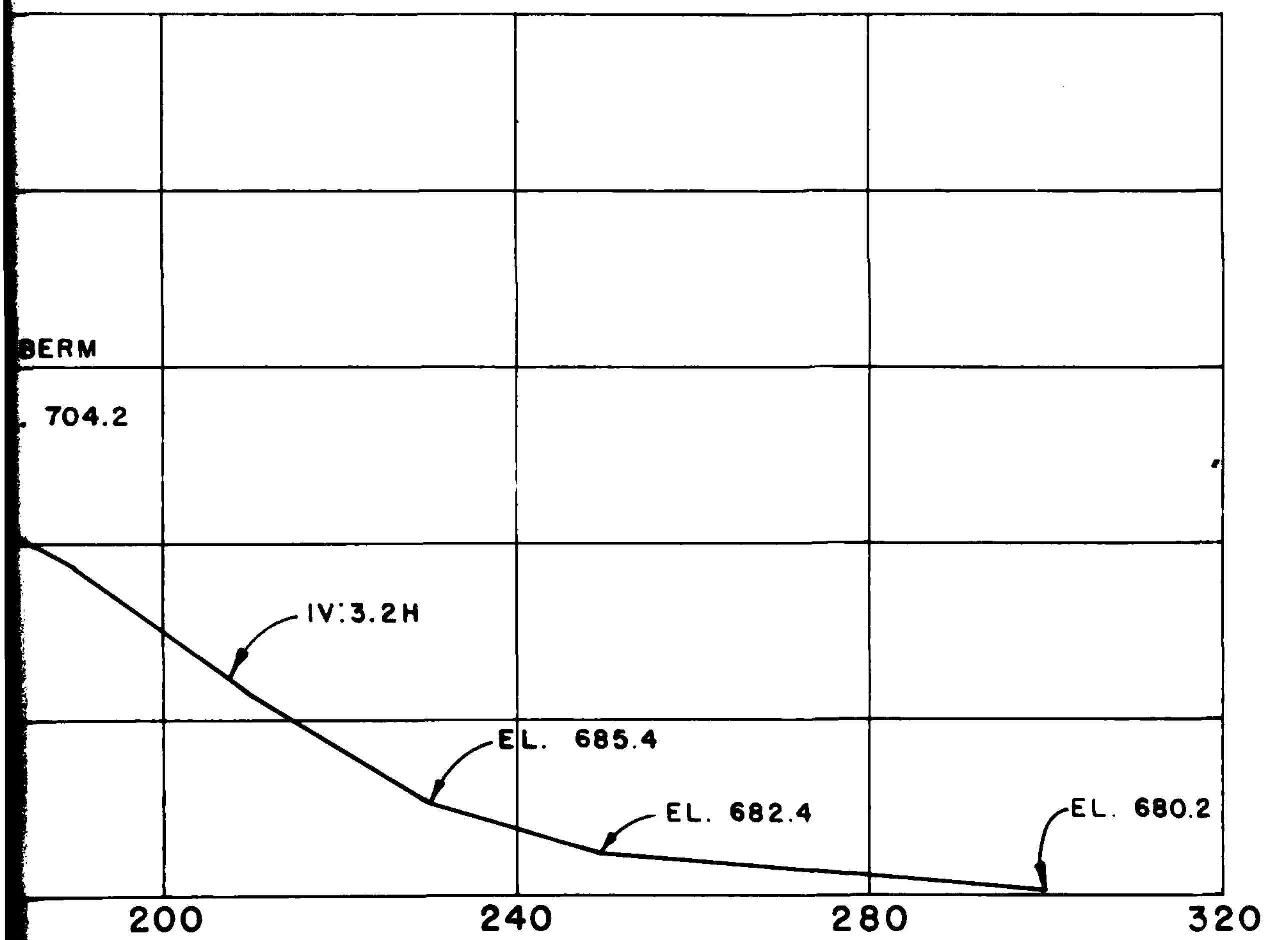
DAM CROSS-SECTION STA. 6+90

SCALES: 1"=10'V., 1"=20' H.



PROFILE SPILLWAY CHANNEL

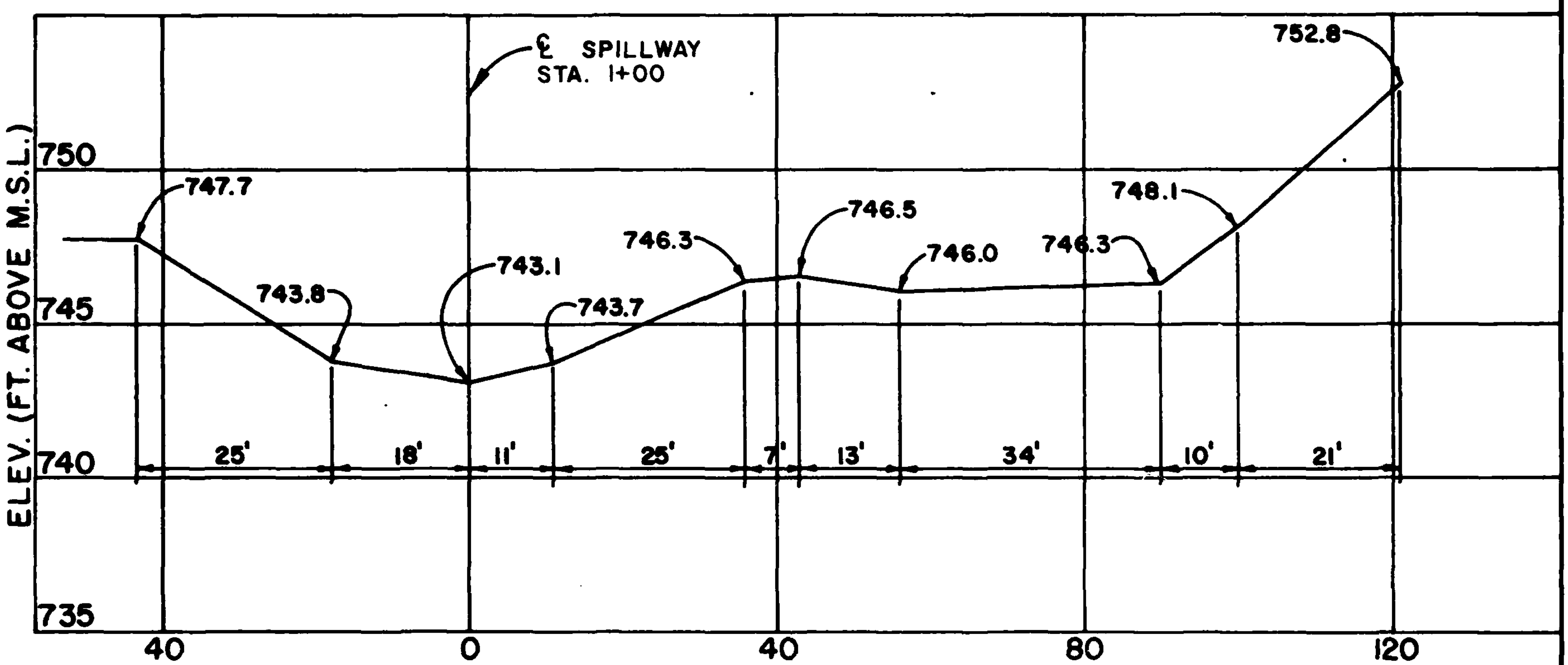
SCALE 1"=10' V., 1"=20' H.



CRANCER LAKE
DAM CROSS-SECTION &
SPILLWAY PROFILE

Horner & Shifrin, Inc. July 1980

PLATE 4



CROSS-SECTION SPILLWAY
SCALES: 1" = 5' V., 1" = 20' H.

CRANCER LAKE
SPILLWAY CROSS-SECTION
Horner & Shifrin, Inc. Sept. 1980

APPENDIX A

INSPECTION PHOTOGRAPHS

NO. 1: CREST AND UPSTREAM FACE OF DAM

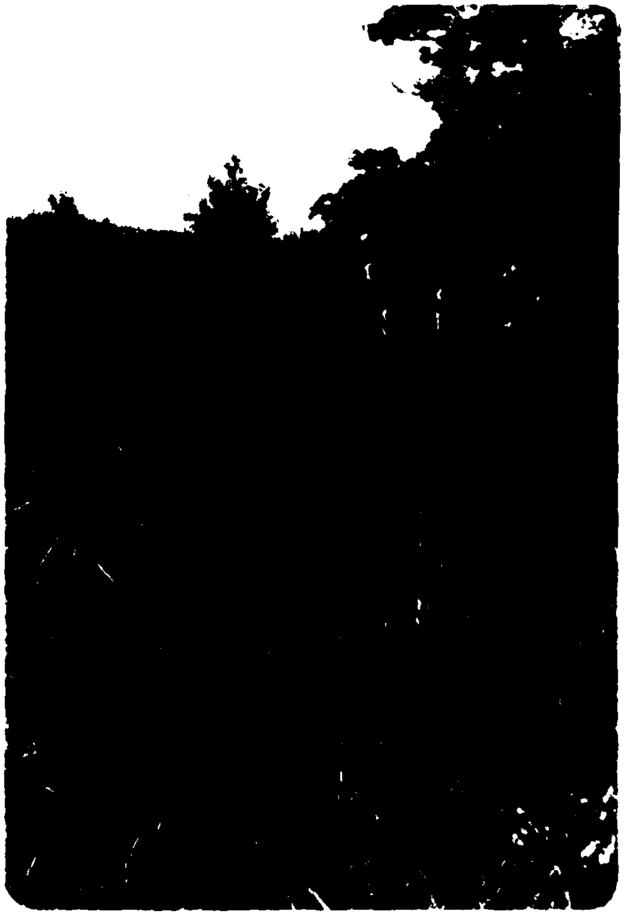
NO. 2: DOWNSTREAM FACE OF DAM AND LEFT ABUTMENT

NO. 3: DOWNSTREAM FACE OF DAM AND RIGHT ABUTMENT

NO. 4: CONCRETE WEIR SPILLWAY

NO. 5: SPILLWAY OUTLET CHANNEL

NO. 6: ERODED AREA OF SPILLWAY OUTLET CHANNEL



NO. 7: CATTAILS AT JUNCTION OF UPPER BERM AND LEFT ABUTMENT

NO. 8: SEEPAGE AT TOE OF DAM NEAR LEFT ABUTMENT

APPENDIX B

HYDROLOGIC AND HYDRAULIC ANALYSES

HYDROLOGIC AND HYDRAULIC COMPUTATIONS

1. The HEC-1 Dam Safety Version (July 1978, Modified 26 February 1979) program was used to develop inflow and outflow hydrographs and dam overtopping analyses, with hydrologic inputs as follows:

   a. Probable maximum precipitation (200 sq. mile, 24-hour value equals 25.0 inches) from Hydrometeorological Report No. 33. The precipitation data used in the analysis of the 1 percent (100-year frequency) flood was provided by the St. Louis District, Corps of Engineers.

   b. Drainage area = 0.162 square miles = 104 acres.

   c. SCS parameters:

   Hydrologic soil group = C (Predominantly Lindley Series, per SCS County Soil Report)

   Soil type CN = 91 (AMC III, PMF condition)
   = 80 (AMC II, 100-year flood condition)

   Time of Concentration (T_c) = $\left(\frac{11.9L^3}{H}\right)^{0.385}$ = 0.105 hours

   Where: T_c = Travel time of water from hydraulically most distant point to point of interest, hours.*
   L = Length of longest watercourse = 0.275 miles
   H = Elevation difference = 86 feet

   Lag Time = 0.60 Tc (SCS Method) = 0.063 hours

*The time of concentration (Tc) was obtained using Method C as described in Figure 30, "Design of Small Dams" by the United States Department of the Interior, Bureau of Reclamation, and was verified using average channel velocity estimates and watercourse lengths.

2. Due to the fact that the channel section downstream of the concrete weir was determined to be considerably narrower than the crest length of the concrete weir, the critical section for determination of spillway capacity was considered to be the channel section. The spillway control section below the concrete weir consists of a broad-crested, trapezoidal section for which conventional weir formulas do not apply. Spillway release rates for these sections were determined as follows:

a. Spillway control section properties (area, "a" and top width, "t") were computed for various depths, "d".

b. It was assumed that flow over the spillway crest would occur at critical depth. Flow at critical depth (Qc) was computed as

$Qc = (\frac{a^3 g}{t})^{0.5}$ for the various depths, "d". Corresponding velocities (v_c) and velocity heads (H_{vc}) were determined using conventional formulas.* Reference, "Handbook of Hydraulics", Fifth Edition, by King & Brater, page 8-7.

c. Static lake levels corresponding to various values passing the spillway were computed as critical depths plus critical velocity heads ($d_c + H_{vc}$) for the spillway and the relationship between lake level and spillway discharge was thus obtained. The procedure neglects the minor insignificant friction losses across the length of the spillway.

3. The profile of the dam crest is irregular and flow over the dam crest cannot be determined by conventional weir formulas. Crest length and elevation data for the dam crest proper were entered into the HEC-1 Program on the $L and the $V cards. The program assumes that flow over the dam crest section occurs at critical depth and computes internally the flow over the dam crest and adds this flow to the flow passing the spillway as entered on the Y4 and Y5 cards.

* $v_c = \frac{Qc}{a}$; $Hvc = \frac{v_c^2}{2g}$

```
A1       ANALYSIS OF DAM OVERTOPPING USING RATIOS OF PMF
A2       HYDROLOGIC-HYDRAULIC ANALYSIS OF SAFETY OF CRANCERS LAKE DAM
A3       RATIOS OF PMF ROUTED THROUGH RESERVOIR
B      288       0       5       0       0       0       0       0       0       0
B1       5
J        1       3       1
J1    0.50    0.55    1.00
K        0  INFLOW                                       1
K1       INFLOW HYDROGRAPH
M        1       2   0.162                   1.0                     1
P        0    25.0     102     120     130
T                                                       -1     -91
W2             0.000
X     -1.0    -.10     2.0
K        1     DAM                                       1
K1       RESERVOIR ROUTING BY MODIFIED PULS
Y                                1       1
Y1       1                                          347.40      -1
Y4   744.0   744.7   745.4   746.0   746.4  746.75  747.35   740.1   748.5   748.7
Y4   749.5   750.3   751.0   751.7
Y5       0      70     214     390     546     750    1180    1810    2082    2745
Y5    3525    4625    5695    6800
$A       0    17.3    20.7    32.1    42.0
$E     720     744     750     760     770
$$   744.0
$D   746.2
$L      40      63     177     417     490     500     600     700     800     950
$V   746.2   746.4   746.7   747.1   747.4   747.8   748.0   748.1   750.0   750.4
K       99
```

```
1A1       ANALYSIS OF DAM OVERTOPPING USING 100-YR FLOOD
A2       HYDROLOGIC-HYDRAULIC ANALYSIS OF SAFETY OF CRANDERS LAKE DAM
A3       100-YR FLOOD ROUTED THROUGH RESERVOIR
B     288       0       5                                                 4
B1      5
J       1       1       1
J1   1.00
K       0   INFLOW                                   1
K1        INFLOW HYDROGRAPH
M       0       2   0.162                     1.0                         1
O     288   7.094
01   .006    .006    .006    .006    .006    .006    .006    .006    .006    .006
01   .006    .006    .006    .006    .006    .006    .006    .006    .006    .006
01   .006    .006    .006    .006    .006    .006    .006    .006    .006    .006
01   .006    .006    .006    .006    .006    .006    .006    .006    .006    .006
01   .006    .006    .006    .006    .006    .006    .006    .006    .006    .006
01   .006    .006    .006    .006    .006    .006    .006    .006    .006    .006
01   .006    .006    .006    .006    .006    .006    .006    .006    .006    .006
01   .006    .006    .014    .014    .014    .014    .014    .014    .014    .014
01   .014    .014    .014    .014    .014    .014    .014    .014    .014    .014
01   .014    .014    .014    .014    .014    .014    .014    .014    .014    .014
01   .014    .014    .014    .014    .014    .014    .014    .014    .024    .024
01   .024    .024    .024    .024    .024    .024    .024    .024    .024    .024
01   .024    .024    .024    .024    .024    .024    .029    .029    .029    .029
01   .029    .029    .040    .040    .040    .040    .040    .040    .129    .129
01   .130    .247    .247    .544    .306    .300    .247    .130    .130    .129
01   .040    .040    .040    .040    .040    .040    .029    .029    .029    .029
01   .029    .029    .024    .024    .024    .024    .024    .024    .024    .024
01   .024    .024    .024    .024    .024    .024    .024    .024    .024    .024
```

100-YR. FLOOD (Cont'd)

O1	.014	.014	.014	.014	.014	.014	.014	.014	.014	.014
O1	.014	.014	.014	.014	.014	.014	.014	.014	.014	.014
O1	.014	.014	.014	.014	.014	.014	.014	.014	.014	.014
O1	.014	.014	.014	.014	.014	.014	.006	.006	.006	.006
O1	.006	.006	.006	.006	.006	.006	.006	.006	.006	.006
O1	.006	.006	.006	.006	.006	.006	.006	.006	.006	.006
O1	.006	.006	.006	.006	.006	.006	.006	.006	.006	.006
O1	.006	.006	.006	.006	.006	.006	.006	.006	.006	.006
O1	.006	.006	.006	.006	.006	.006	.006	.006	.006	.006
O1	.006	.006	.006	.006	.006	.006	.006	.006	.006	.006
O1	.006	.006	.006	.006	.006	.006	.006	.006		
T							1	-80		
WQ		[illegible]								
X	1.[illegible]	.1[illegible]	2.0							
[illegible]	1	DAM					1			
K1	RESERVOIR ROUTING BY [illegible]									
Y					1	1				
Y1	1						747.40	1		
Y4	744.0	744.7	745.4	746.[illegible]	746.4	746.9	747.35	748.1	748.5	748.9
Y4	749.5	750.3	751.0	751.[illegible]						
Y5	0	70	214	[illegible]	540	750	1101	1600	2207	2745
Y5	1525	2425	3205	[illegible]						
$A	0	17.3	23.7	32.[illegible]	42.0					
$E	600	744	750	7[illegible]	[illegible]					
$1	744.0									
$0	744.2									
$L	40	[illegible]	177	4[illegible]	[illegible]	[illegible]	[illegible]	708	00	858
$V	744.2	746.4	746.[illegible]	747.[illegible]	[illegible]	747.5	748.0	748.2	752.0	756.4
K	[illegible]									

```
ANALYSIS OF DAM OVERTOPPING USING RATIOS OF PMF
HYDROLOGIC-HYDRAULIC ANALYSIS OF SAFETY OF CRANCERS LAKE DAM
RATIOS OF PMF ROUTED THROUGH RESERVOIR

                              JOB SPECIFICATION
   NQ      NHR     NMIN     IDAY      IHR     IMIN    METRC     IPLT     IPRT    NSTAN
  288        0        5        0        0        0        0        0        0        0
                            JOPER      NWT    LROPT    TRACE
                                5        0        0        0


                     MULTI PLAN ANALYSES TO BE PERFORMED
                        NPLAN= 1 NRTIO= 3 LRTIO= 1
  RTIOS=     .50     .55    1.00


**********          **********          **********          **********          **********

                          SUB-AREA RUNOFF COMPUTATION

   INFLOW HYDROGRAPH

            ISTAQ    ICOMP    IECON    ITAPE     JPLT     JPRT    INAME   ISTAGE    IAUTO
           INFLOW        0        0        0        0        0        1        0        0

                                HYDROGRAPH DATA
   IHYDG    IUHG    TAREA     SNAP    TRSDA    TRSPC    RATIO    ISNOW    ISAME    LOCAL
       1       2      .16     0.00      .16     1.00    0.000        0        1        0

                                  PRECIP DATA
          SPFE      PMS       R6      R12      R24      R48      R72      R96
          0.00    25.00   102.00   120.00   130.00     0.00     0.00     0.00

                                   LOSS DATA
 LROPT   STRKR   DLTKR   RTIOL   ERAIN   STRKS   RTIOK   STRTL   CNSTL   ALSMX   RTIMP
     0    0.00    0.00    1.00    0.00    0.00    1.00    1.00  -91.00    0.00    0.00

   CURVE NO =  -91.00  WETNESS =   -1.00  EFFECT CN =   91.00

                              UNIT HYDROGRAPH DATA
                            TC=  0.00    LAG=   .06

                                 RECESSION DATA
                   STRTQ=   -1.00     QRCSN=    -.10    RTIOR= 2.00

   TIME INCREMENT TOO LARGE--(NHQ IS GT LAG/2)

  UNIT HYDROGRAPH  6 END OF PERIOD ORDINATES, TC=     0.00 HOURS, LAG=    .06  VOL= 1.00
 683.      426.      111.       30.        3.        2.
```

0

END-OF-PERIOD FLOW

MO.DA	HR.MN	PERIOD	RAIN	EXCS	LOSS	COMP Q		MO.DA	HR.MN	PERIOD	RAIN	EXCS	LOSS	COMP Q
1.01	.05	1	.01	0.00	.01	0.		1.01	12.05	145	.21	.21	.01	176.
1.01	.10	2	.01	0.00	.01	0.		1.01	12.10	146	.21	.21	.00	238.
1.01	.15	3	.01	0.00	.01	0.		1.01	12.15	147	.21	.21	.00	255.
1.01	.20	4	.01	0.00	.01	0.		1.01	12.20	148	.21	.21	.00	260.
1.01	.25	5	.01	0.00	.01	0.		1.01	12.25	149	.21	.21	.00	261.
1.01	.30	6	.01	0.00	.01	0.		1.01	12.30	150	.21	.21	.00	262.
1.01	.35	7	.01	0.00	.01	0.		1.01	12.35	151	.21	.21	.00	262.
1.01	.40	8	.01	0.00	.01	0.		1.01	12.40	152	.21	.21	.00	262.
1.01	.45	9	.01	0.00	.01	0.		1.01	12.45	153	.21	.21	.00	262.
1.01	.50	10	.01	0.00	.01	0.		1.01	12.50	154	.21	.21	.00	263.
1.01	.55	11	.01	0.00	.01	0.		1.01	12.55	155	.21	.21	.00	263.
1.01	1.00	12	.01	0.00	.01	0.		1.01	13.00	156	.21	.21	.00	263.
1.01	1.05	13	.01	0.00	.01	0.		1.01	13.05	157	.26	.25	.00	292.
1.01	1.10	14	.01	0.00	.01	0.		1.01	13.10	158	.26	.25	.00	310.
1.01	1.15	15	.01	.00	.01	0.		1.01	13.15	159	.26	.25	.00	314.
1.01	1.20	16	.01	.00	.01	0.		1.01	13.20	160	.26	.25	.00	316.
1.01	1.25	17	.01	.00	.01	1.		1.01	13.25	161	.26	.25	.00	316.
1.01	1.30	18	.01	.00	.01	1.		1.01	13.30	162	.26	.25	.00	317.
1.01	1.35	19	.01	.00	.01	2.		1.01	13.35	163	.26	.25	.00	317.
1.01	1.40	20	.01	.00	.01	2.		1.01	13.40	164	.26	.25	.00	317.
1.01	1.45	21	.01	.00	.01	2.		1.01	13.45	165	.26	.25	.00	317.
1.01	1.50	22	.01	.00	.01	3.		1.01	13.50	166	.26	.25	.00	317.
1.01	1.55	23	.01	.00	.01	3.		1.01	13.55	167	.26	.25	.00	317.
1.01	2.00	24	.01	.00	.01	4.		1.01	14.00	168	.26	.25	.00	317.
1.01	2.05	25	.01	.00	.01	4.		1.01	14.05	169	.32	.32	.00	361.
1.01	2.10	26	.01	.00	.01	4.		1.01	14.10	170	.32	.32	.00	387.
1.01	2.15	27	.01	.00	.01	5.		1.01	14.15	171	.32	.32	.00	395.
1.01	2.20	28	.01	.00	.01	5.		1.01	14.20	172	.32	.32	.00	397.
1.01	2.25	29	.01	.00	.01	5.		1.01	14.25	173	.32	.32	.00	397.
1.01	2.30	30	.01	.00	.01	5.		1.01	14.30	174	.32	.32	.00	398.
1.01	2.35	31	.01	.00	.01	6.		1.01	14.35	175	.32	.32	.00	398.
1.01	2.40	32	.01	.00	.01	6.		1.01	14.40	176	.32	.32	.00	398.
1.01	2.45	33	.01	.01	.01	6.		1.01	14.45	177	.32	.32	.00	398.
1.01	2.50	34	.01	.01	.01	6.		1.01	14.50	178	.32	.32	.00	398.
1.01	2.55	35	.01	.01	.01	7.		1.01	14.55	179	.32	.32	.00	398.
1.01	3.00	36	.01	.01	.01	7.		1.01	15.00	180	.32	.32	.00	398.
1.01	3.05	37	.01	.01	.01	7.		1.01	15.05	181	.19	.19	.00	313.
1.01	3.10	38	.01	.01	.01	7.		1.01	15.10	182	.39	.39	.00	393.
1.01	3.15	39	.01	.01	.01	8.		1.01	15.15	183	.39	.39	.00	460.
1.01	3.20	40	.01	.01	.01	8.		1.01	15.20	184	.58	.58	.00	610.
1.01	3.25	41	.01	.01	.01	8.		1.01	15.25	185	.68	.68	.00	762.
1.01	3.30	42	.01	.01	.01	8.		1.01	15.30	186	1.65	1.64	.00	1485.
1.01	3.35	43	.01	.01	.01	8.		1.01	15.35	187	2.71	2.71	.01	2634.
1.01	3.40	44	.01	.01	.01	9.		1.01	15.40	188	1.07	1.06	.00	2071.
1.01	3.45	45	.01	.01	.01	9.		1.01	15.45	189	.68	.68	.00	1266.
1.01	3.50	46	.01	.01	.01	9.		1.01	15.50	190	.58	.58	.00	896.
1.01	3.55	47	.01	.01	.01	9.		1.01	15.55	191	.39	.39	.00	641.
1.01	4.00	48	.01	.01	.01	9.		1.01	16.00	192	.39	.39	.00	525.
1.01	4.05	49	.01	.01	.01	9.		1.01	16.05	193	.30	.30	.00	433.
1.01	4.10	50	.01	.01	.01	10.		1.01	16.10	194	.30	.30	.00	388.

END-OF-PERIOD FLOW (Cont'd)

1.01	4.15	51	.01	.01	.01	10.	1.01	16.15	195	.30	.30	.00	376.
1.01	4.20	52	.01	.01	.01	10.	1.01	16.20	196	.30	.30	.00	373.
1.01	4.25	53	.01	.01	.01	10.	1.01	16.25	197	.30	.30	.00	373.
1.01	4.30	54	.01	.01	.01	10.	1.01	16.30	198	.30	.30	.00	373.
1.01	4.35	55	.01	.01	.01	10.	1.01	16.35	199	.30	.30	.00	373.
1.01	4.40	56	.01	.01	.01	10.	1.01	16.40	200	.30	.30	.00	373.
1.01	4.45	57	.01	.01	.01	10.	1.01	16.45	201	.30	.30	.00	373.
1.01	4.50	58	.01	.01	.01	11.	1.01	16.50	202	.30	.30	.00	373.
1.01	4.55	59	.01	.01	.01	11.	1.01	16.55	203	.30	.30	.00	373.
1.01	5.00	60	.01	.01	.01	11.	1.01	17.00	204	.30	.30	.00	373.
1.01	5.05	61	.01	.01	.01	11.	1.01	17.05	205	.23	.23	.00	329.
1.01	5.10	62	.01	.01	.01	11.	1.01	17.10	206	.23	.23	.00	302.
1.01	5.15	63	.01	.01	.00	11.	1.01	17.15	207	.23	.23	.00	295.
1.01	5.20	64	.01	.01	.00	11.	1.01	17.20	208	.23	.23	.00	293.
1.01	5.25	65	.01	.01	.00	11.	1.01	17.25	209	.23	.23	.00	293.
1.01	5.30	66	.01	.01	.00	11.	1.01	17.30	210	.23	.23	.00	293.
1.01	5.35	67	.01	.01	.00	12.	1.01	17.35	211	.23	.23	.00	293.
1.01	5.40	68	.01	.01	.00	12.	1.01	17.40	212	.23	.23	.00	293.
1.01	5.45	69	.01	.01	.00	12.	1.01	17.45	213	.23	.23	.00	293.
1.01	5.50	70	.01	.01	.00	12.	1.01	17.50	214	.23	.23	.00	293.
1.01	5.55	71	.01	.01	.00	12.	1.01	17.55	215	.23	.23	.00	293.
1.01	6.00	72	.01	.01	.00	12.	1.01	18.00	216	.23	.23	.00	293.
1.01	6.05	73	.06	.05	.02	[illegible]	1.01	18.05	217	.02	.02	.00	249.
1.01	6.10	74	.06	.05	.02	[illegible]	1.01	18.10	218	.02	.02	.00	233.
1.01	6.15	75	.06	.05	.02	[illegible]	1.01	18.15	219	.02	.02	.00	217.
1.01	6.20	76	.06	.05	.02	58.	1.01	18.20	220	.02	.02	.00	203.
1.01	6.25	77	.06	.05	.01	60.	1.01	18.25	221	.02	.02	.00	189.
1.01	6.30	78	.06	.05	.01	61.	1.01	18.30	222	.02	.02	.00	176.
1.01	6.35	79	.06	.05	.01	62.	1.01	18.35	223	.02	.02	.00	165.
1.01	6.40	80	.06	.05	.01	63.	1.01	18.40	224	.02	.02	.00	154.
1.01	6.45	81	.06	.05	.01	64.	1.01	18.45	225	.02	.02	.00	143.
1.01	6.50	82	.06	.05	.01	64.	1.01	18.50	226	.02	.02	.00	134.
1.01	6.55	83	.06	.05	.01	65.	1.01	18.55	227	.02	.02	.00	125.
1.01	7.00	84	.06	.05	.01	66.	1.01	19.00	228	.02	.02	.00	116.
1.01	7.05	85	.06	.05	.01	66.	1.01	19.05	229	.02	.02	.00	109.
1.01	7.10	86	.06	.05	.01	67.	1.01	19.10	230	.02	.02	.00	101.
1.01	7.15	87	.06	.05	.01	68.	1.01	19.15	231	.02	.02	.00	94.
1.01	7.20	88	.06	.05	.01	68.	1.01	19.20	232	.02	.02	.00	88.
1.01	7.25	89	.06	.05	.01	68.	1.01	19.25	233	.02	.02	.00	82.
1.01	7.30	90	.06	.06	.01	69.	1.01	19.30	234	.02	.02	.00	77.
1.01	7.35	91	.06	.06	.01	69.	1.01	19.35	235	.02	.02	.00	72.
1.01	7.40	92	.06	.06	.01	70.	1.01	19.40	236	.02	.02	.00	67.
1.01	7.45	93	.06	.06	.01	70.	1.01	19.45	237	.02	.02	.00	62.
1.01	7.50	94	.06	.06	.01	70.	1.01	19.50	238	.02	.02	.00	58.
1.01	7.55	95	.06	.06	.01	71.	1.01	19.55	239	.02	.02	.00	54.
1.01	8.00	96	.06	.06	.01	71.	1.01	20.00	240	.02	.02	.00	51.
1.01	8.05	97	.06	.06	.01	71.	1.01	20.05	241	.02	.02	.00	47.
1.01	8.10	98	.06	.06	.01	72.	1.01	20.10	242	.02	.02	.00	44.
1.01	8.15	99	.06	.06	.01	72.	1.01	20.15	243	.02	.02	.00	41.
1.01	8.20	100	.06	.06	.00	72.	1.01	20.20	244	.02	.02	.00	38.
1.01	8.25	101	.06	.06	.00	72.	1.01	20.25	245	.02	.02	.00	36.
1.01	8.30	102	.06	.06	.00	72.	1.01	20.30	246	.02	.02	.00	33.

END-OF-PERIOD FLOW (Cont'd)

1.01	8.35	103	.06	.06	.00	73.	1.01	20.35	247	.02	.02	.00	31.
1.01	8.40	104	.06	.06	.00	73.	1.01	20.40	248	.02	.02	.00	29.
1.01	8.45	105	.06	.06	.00	73.	1.01	20.45	249	.02	.02	.00	27.
1.01	8.50	106	.06	.06	.00	73.	1.01	20.50	250	.02	.02	.00	26.
1.01	8.55	107	.06	.06	.00	73.	1.01	20.55	251	.02	.02	.00	26.
1.01	9.00	108	.06	.06	.00	74.	1.01	21.00	252	.02	.02	.00	26.
1.01	9.05	109	.06	.06	.00	74.	1.01	21.05	253	.02	.02	.00	26.
1.01	9.10	110	.06	.06	.00	74.	1.01	21.10	254	.02	.02	.00	26.
1.01	9.15	111	.06	.06	.00	74.	1.01	21.15	255	.02	.02	.00	26.
1.01	9.20	112	.06	.06	.00	74.	1.01	21.20	256	.02	.02	.00	26.
1.01	9.25	113	.06	.06	.00	74.	1.01	21.25	257	.02	.02	.00	26.
1.01	9.30	114	.06	.06	.00	74.	1.01	21.30	258	.02	.02	.00	26.
1.01	9.35	115	.06	.06	.00	74.	1.01	21.35	259	.02	.02	.00	26.
1.01	9.40	116	.06	.06	.00	75.	1.01	21.40	260	.02	.02	.00	26.
1.01	9.45	117	.06	.06	.00	75.	1.01	21.45	261	.02	.02	.00	26.
1.01	9.50	118	.06	.06	.00	75.	1.01	21.50	262	.02	.02	.00	26.
1.01	9.55	119	.06	.06	.00	75.	1.01	21.55	263	.02	.02	.00	26.
1.01	10.00	120	.06	.06	.00	75.	1.01	22.00	264	.02	.02	.00	26.
1.01	10.05	121	.06	.06	.00	75.	1.01	22.05	265	.02	.02	.00	26.
1.01	10.10	122	.06	.06	.00	75.	1.01	22.10	266	.02	.02	.00	26.
1.01	10.15	123	.06	.06	.00	75.	1.01	22.15	267	.02	.02	.00	26.
1.01	10.20	124	.06	.06	.00	75.	1.01	22.20	268	.02	.02	.00	26.
1.01	10.25	125	.06	.06	.00	75.	1.01	22.25	269	.02	.02	.00	26.
1.01	10.30	126	.06	.06	.00	75.	1.01	22.30	270	.02	.02	.00	26.
1.01	10.35	127	.06	.06	.00	75.	1.01	22.35	271	.02	.02	.00	26.
1.01	10.40	128	.06	.06	.00	76.	1.01	22.40	272	.02	.02	.00	26.
1.01	10.45	129	.06	.06	.00	76.	1.01	22.45	273	.02	.02	.00	26.
1.01	10.50	130	.06	.06	.00	76.	1.01	22.50	274	.02	.02	.00	26.
1.01	10.55	131	.06	.06	.00	76.	1.01	22.55	275	.02	.02	.00	26.
1.01	11.00	132	.06	.06	.00	76.	1.01	23.00	276	.02	.02	.00	26.
1.01	11.05	133	.06	.06	.00	76.	1.01	23.05	277	.02	.02	.00	26.
1.01	11.10	134	.06	.06	.00	76.	1.01	23.10	278	.02	.02	.00	26.
1.01	11.15	135	.06	.06	.00	76.	1.01	23.15	279	.02	.02	.00	26.
1.01	11.20	136	.06	.06	.00	76.	1.01	23.20	280	.02	.02	.00	26.
1.01	11.25	137	.06	.06	.00	76.	1.01	23.25	281	.02	.02	.00	26.
1.01	11.30	138	.06	.06	.00	76.	1.01	23.30	282	.02	.02	.00	26.
1.01	11.35	139	.06	.06	.00	76.	1.01	23.35	283	.02	.02	.00	26.
1.01	11.40	140	.06	.06	.00	76.	1.01	23.40	284	.02	.02	.00	26.
1.01	11.45	141	.06	.06	.00	76.	1.01	23.45	285	.02	.02	.00	26.
1.01	11.50	142	.06	.06	.00	76.	1.01	23.50	286	.02	.02	.00	26.
1.01	11.55	143	.06	.06	.00	76.	1.01	23.55	287	.02	.02	.00	26.
1.01	12.00	144	.06	.06	.00	76.	1.02	0.00	288	.02	.02	.00	26.
									SUM	32.50	31.34	1.16	41605.
										(825.)(	796.)(	29.)(	1178.12)

	PEAK	6-HOUR	24-HOUR	72-HOUR	TOTAL VOLUME
CFS	2634.	441.	144.	144.	41573.
CMS	75.	12.	4.	4.	1178.
INCHES		25.32	33.17	33.17	33.17
MM		643.25	842.54	842.54	842.54
AC-FT		219.	286.	[illegible]	286.
THOUS CU M		270.	353.	353.	353.

	3525.00	4625.00	5695.00	6800.00	
SURFACE AREA=	0.	19.	24.	33.	42.
CAPACITY=	0.	347.	476.	754.	1124.
ELEVATION=	690.	744.	750.	760.	770.

CREL	SPWID	COQW	EXPW	ELEVL	COOL	CAREA	EXPL

SUMMARY OF DAM SAFETY ANALYSIS

PMF

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	744.00	744.00	746.20
STORAGE	347.	347.	392.
OUTFLOW	0.	0.	460.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
.50	746.11	0.00	390.	435.	0.00	15.00	0.00
.55	746.27	.07	[illegible]	[illegible]	.25	[illegible]	0.00
1.00	747.22	1.02	413.	1483.	1.25	15.75	0.00

SUMMARY OF DAM SAFETY ANALYSIS

100-YR. FLOOD

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	744.00	744.00	746.20
STORAGE	347.	347.	392.
OUTFLOW	0.	0.	460.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
1.00	744.97	0.00	364.	126.	0.00	12.50	0.00